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Edition 1.1 2015-04

CONSOLIDATED VERSION

colour inside

Cable networks for television signals, sound signals and interactive services – Part 7-1: Hybrid Fibre Coax Outside Plant status monitoring – Physical (PHY) Layer Specification

IEC 60728-7-1:2003-10+AMD1:2015-04 CSV(en)

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Cable networks for television signals, sound signals and interactive services – Part 7-1: Hybrid Fibre Coax Outside Plant status monitoring – Physical (PHY) Layer Specification

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CABLE NETWORKS FOR TELEVISION SIGNALS, SOUND SIGNALS AND INTERACTIVE SERVICES –

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In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions and deletions are displayed in red, with deletions being struck through. A separate Final version with all changes accepted is available in this publication.

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International Standard IEC 60728-7-1 has been prepared by technical area 5: Cable networks for television signals, sound signals and interactive services, of IEC technical committee 100: Audio, video and multimedia systems and equipment.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

The following differences exist in some countries:

The Japanese *de facto* standard (NCTEA S-006) concerning requirements for the HFC outside plant management, which was published in 1995, has already been available in Japan. The purpose of this standard is to support the design and implementation of interoperable management systems for HFC cable networks used in Japan. (see Table 4)

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INTRODUCTION

~~Standards of the IEC 60728 series deal with cable networks for television signals, sound signals and interactive services including equipment, systems and installations for~~

- ~~head-end reception, processing and distribution of television and sound signals and their associated data signals, and~~
- ~~processing, interfacing and transmitting all kinds of signals for interactive services~~

~~using all applicable transmission media.~~

~~All kinds of networks like~~

- ~~CATV-networks,~~
- ~~MATV-networks and SMATV-networks,~~
- ~~individual receiving networks~~

~~and all kinds of equipment, systems and installations installed in such networks, are within this scope.~~

Standards and other deliverables of the IEC 60728 series deal with cable networks including equipment and associated methods of measurement for headend reception, processing and distribution of television and sound signals and for processing, interfacing and transmitting all kinds of data signals for interactive services using all applicable transmission media. These signals are typically transmitted in networks by frequency-multiplexing techniques.

This includes for instance

- regional and local broadband cable networks,
- extended satellite and terrestrial television distribution systems,
- individual satellite and terrestrial television receiving systems,

and all kinds of equipment, systems and installations used in such cable networks, distribution and receiving systems.

The extent of this standardization work is from the antennas~~,~~ and/or special signal source inputs to the headend or other interface points to the network up to ~~the system outlet or~~ the terminal input~~, where no system outlet exists~~ of the customer premises equipment.

The standardization work will consider coexistence with users of the RF spectrum in wired and wireless transmission systems.

The standardization of any user terminals (i.e. tuners, receivers, decoders, multimedia terminals, etc.) as well as of any coaxial and optical cables and accessories ~~therefore~~ thereof is excluded.

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CABLE NETWORKS FOR TELEVISION SIGNALS, SOUND SIGNALS AND INTERACTIVE SERVICES –

Part 7-1: Hybrid Fibre Coax Outside Plant status monitoring – Physical (PHY) layer specification

1 Scope

This part of IEC 60728 specifies requirements for The Hybrid Fibre Coax (HFC) Outside Plant (OSP) Physical (PHY) Layer Specification and is part of the series of specifications developed by the Hybrid Management Sub-Layer (HMS) subcommittee under the SCTE. The purpose of the HMS specification is to support the design and implementation of interoperable management systems for evolving HFC cable networks. The HMS Physical (PHY) Layer Specification describes the physical layer portion of the protocol stack used for communication between HMS-compliant transponders interfacing to managed outside plant network elements (NE) and a centralized head-end element (HE).

This standard describes the PHY layer requirements that must be implemented by all *Type 2* and *Type 3* compliant OSP HMS transponders on the HFC plant and the controlling equipment in the head-end. Any exceptions to compliance with this standard will be specifically noted herein as necessary. Refer to Table 1 for a full definition of the type classifications.

Electromagnetic Compatibility (EMC) is not specified in this standard and is left to the vendor to ensure compliance with local EMC regulatory requirements. Other than operating temperature, physical parameters such as shock, vibration, humidity, etc., are also not specified and left to the vendor’s discretion.

Transponder type classifications referenced within the HMS series of standards are defined in Table 1.

Table 1 – Transponder type classifications

Type	Description	Application
Type 0	Refers to legacy transponder equipment, which is incapable of supporting the HMS specifications	This transponder interfaces with legacy network equipment through proprietary means. This transponder could be managed through the same management applications as the other types through proxies or other means at the head-end
Type 1	Refers to stand-alone transponder equipment (legacy or new) which can be upgraded to support the HMS specifications	This transponder interfaces with legacy network equipment through proprietary means. Type 1 is a standards-compliant transponder (either manufactured to the standard or upgraded) that connects to legacy network equipment via a proprietary interface
Type 2	Refers to a stand-alone, HMS-compliant transponder	This transponder interfaces with network equipment designed to support the electrical and physical specifications defined in the HMS standards. It can be factory or field-installed. Its RF connection is independent of the monitored NE
Type 3	Refers to a stand-alone or embedded, HMS-compliant transponder	This transponder interfaces with network equipment designed to support the electrical specifications defined in the HMS standards. It may or may not support the physical specifications defined in the HMS standards. It can be factory-installed. It may or may not be field-installed. Its RF connection is through the monitored NE

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2 Normative references

None.

3 Terms, definitions and abbreviations

For the purposes of this document, the following terms and definitions apply.

3.1
forward ~~spectrum~~ path band
~~the pass-band~~ continuous set of frequencies in HFC cable systems with a lower edge of between 48 MHz and 87,5 MHz, depending on the particular geographical area, and an upper edge that is typically in the range of 300 MHz to ~~860~~ 1 000 MHz depending on implementation

Note 1 to entry: Due to different channel spacing plans in use, this upper frequency limit may not be exactly 1 000 MHz, but some megahertz higher, e.g. 1 002 MHz or 1 006 MHz. The notation 1 000 MHz in this standard is intended to include such small deviations.

3.2
full ~~spectrum~~ path band
~~combined~~ combination of forward ~~and return spectrums~~ path band and return path band in HFC cable systems ~~and excludes~~ excluding any guard band

3.3
guard band
unused frequency band between the upper edge of the usable return ~~spectrum~~ path band and the lower edge of the usable forward ~~spectrum~~ path band in HFC cable systems

3.4
network element (NE)
active element in the outside plant that is capable of receiving commands from a head-end element (HE) in the head-end and, as necessary, providing status information and alarms back to the HE

3.5
open system interconnection (OSI)
framework of International Organization for Standardization (ISO) standards for communication between multi-vendor systems that organizes the communication process into seven different categories that are placed in a layered sequence based on the relationship to the user. Each layer uses the layer immediately below it and provides services to the layer above. Layers 7 through 4 deal with end-to-end communication between the message source and destination, and layers 3 through 1 deal with network functions

3.6
physical (PHY) layer
layer 1 in the Open System Interconnection (OSI) architecture; the layer that provides services to transmit bits or groups of bits over a transmission link between open systems and which entails electrical, mechanical and handshaking procedures

3.7
return ~~spectrum~~ path band
~~pass-band~~ continuous set of frequencies in HFC cable systems with a lower edge of 5 MHz and an upper edge that is typically in the range of 42 MHz to 65 MHz depending on the particular geographical area

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3.8
transponder
device in the outside plant that interfaces to outside plant NEs and relays status and alarm information to the HE. It can interface with an active NE via an arrangement of parallel analogue, parallel digital and serial ports

3.9
un-modulated carrier
carrier resting on the 'mark' frequency rather than on the channel's centre frequency

3.10 Abbreviated terms

ANSI	American National Standards Institute
BER	Bit Error Rate
C/R	Carrier-to-Noise Ratio
C/(N+I)	Carrier to Noise-plus-Interference Ratio
CW	Continuous Wave
EMC	Electromagnetic Compatibility
FSK	Frequency Shift Keying
HE	Head-end Element
HFC	Hybrid Fibre Coax
HMS	Hybrid Management Sub-Layer
LSB	Least Significant Bit
MSB	Most Significant Bit
NE	Network Element
MAC	Media Access Control
OSP	Outside Plant
PHY	Physical
RF	Radio Frequency
SCTE	Society of Cable Telecommunications Engineers

4 HMS reference architecture forward and return channel specifications

The reference architecture for the HMS series of specifications is illustrated in Figure 1.

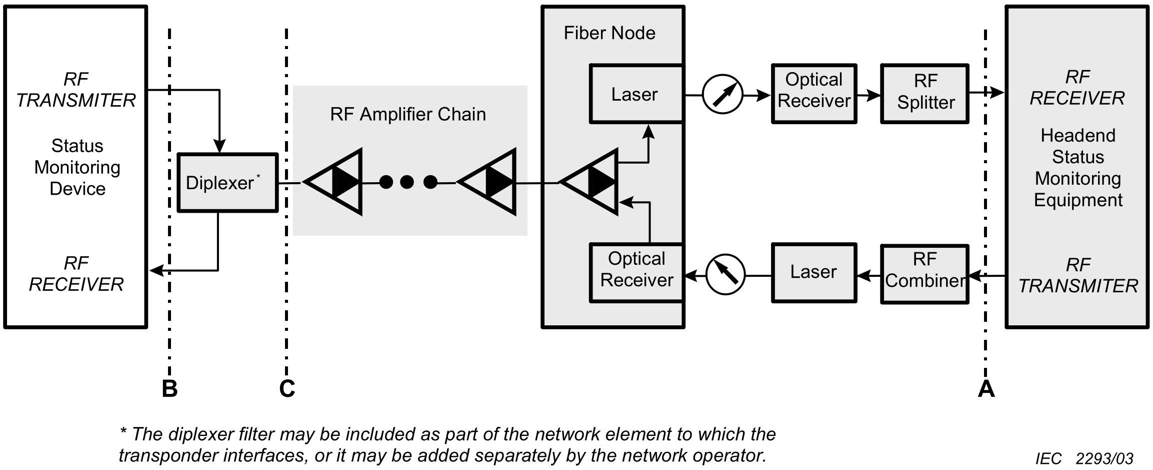

Figure 1 – HMS reference architecture diagram

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All quantities relating to forward channel transmission or reverse channel reception are measured at point A in Figure 1. All quantities relating to forward channel reception or reverse channel transmission are measured at point B for two-port devices and point C for single port devices as shown in Figure 1.

4.1 HMS specification documents

A list of documents in the HMS specifications family is provided in Table 2.

Table 2 – HMS document family

HMS notation	Title
SCTE HMS PHY	HMS Outside Plant Status Monitoring – Physical (PHY) Layer Specification
SCTE HMS MAC	HMS Outside Plant Status Monitoring – Media Access Control (MAC) Layer Specification
SCTE HMS PSTIB	HMS Outside Plant Status Monitoring – Power Supply to Transponder Interface Bus (PSTIB) Specification
SCTE HMS ALARMS MIB	HMS Alarms Management Information Base
SCTE HMS COMMON MIB	HMS Common Management Information Base
SCTE HMS FIBERNODE MIB	HMS Fiber Node Management Information Base
SCTE HMS PROPERTY MIB	HMS Alarm Property Management Information Base
SCTE HMS PS MIB	HMS Power Supply Management Information Base
SCTE ROOT MIB	SCTE Root Management Information Base
SCTE HMS GEN MIB	HMS Power Supply Generator Management Information Base
SCTE HMS TIB MIB	HMS Transponder Interface Bus Management Information Base
SCTE HMS DOWNLOAD MIB	HMS Transponder Firmware Download Management Information Base
SCTE HMS TREE MIB	HMS Root Object Identifiers Management Information Base

4.2 Functional assumptions

4.2.1 Forward path band and return ~~spectrum~~ path band

The forward ~~spectrum~~ path band in HFC cable systems refers to the ~~pass band~~ continuous set of frequencies with a lower edge of between 48 MHz and 87,5 MHz, depending on the particular geographical area, and an upper edge that is typically in the range of 300 MHz to ~~860~~ 1 000 MHz depending on implementation. Analogue television signals in 6 MHz or 8 MHz channels are assumed to be present on the forward ~~spectrum~~ path band as well as other narrowband and wideband digital signals.

The return ~~spectrum~~ path band in HFC cable systems refers to the pass band of frequencies with a lower edge of 5 MHz and an upper edge that is typically in the range of 42 MHz to 65 MHz depending on the particular geographical area. Narrowband and wideband digital signals may be present on the return ~~spectrum~~ path band as well as analogue television signals in 6 MHz or 8 MHz channels.

The full ~~spectrum~~ path band in HFC cable systems refers to the combined forward and return ~~spectrums~~ path bands and excludes any guard band. The guard band refers to the unused frequency band between the upper edge of the usable return ~~spectrum~~ path band and the lower edge of the usable forward ~~spectrum~~ path band. Specific limits on forward and return ~~spectrum~~ path band for various geographical areas are detailed in Table 3.

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Table 3 – Spectral limits by geographical area (North America and Europe)

Geography	Return ~~spectrum~~ path band		Forward ~~spectrum~~ path band	
	Minimum frequency	**Guard band lower limit**	**Guard band upper limit**	**Maximum frequency**
North America	5 MHz	42 MHz	48 MHz	1 000 GHz
Europe 1	5 MHz	30 MHz	47 MHz	862 MHz
Europe 2	5 MHz	50 MHz	70 MHz	~~862~~ 1 000 MHz
Europe 3	5 MHz	65 MHz	87,5 MHz	~~862~~ 1 000 MHz

4.2.2 Transmission levels

The nominal level of the forward ~~spectrum~~ path band HMS carrier(s) is targeted to be no higher than –10 dB relative to analogue video nominal carrier levels. The nominal power level of the return ~~spectrum~~ path band HMS carrier(s) will be as low as possible to achieve the required margin above noise and interference. Uniform power loading per unit bandwidth is commonly followed in setting signal levels on the return ~~spectrum~~ path band, with specific levels established by the cable network operator to achieve the required carrier-to-noise and carrier-to-interference ratios.

5 Physical layer specification

This clause describes version 1.0 of the HMS PHY layer specification. The PHY layer describes rules that govern the transmission of bytes from one device to another. The specific requirements of the HMS PHY layer are detailed in this clause.

5.1 Separate forward and return channels

The one-way communication channel from the HE to a managed OSP NE is referred to as the *forward* channel. The one-way communication channel from a managed OSP NE to the HE is referred to as the *return* channel. Both the forward and the return channels are placed on specific centre frequencies. The forward and return channels' centre frequencies are different. Since the NEs only listen to the forward channel, they cannot listen to return channel transmissions from other NEs. This channel separation is a result of the sub-band split between the forward and return portions of the typical HFC plant spectrum.

5.2 Single forward and return path channels

To keep management of carrier frequencies simple, each HMS-based status monitoring system has a single forward channel and a single return channel. This does not preclude the use of multiple monitoring systems, each with its own individual forward and return RF channels.

5.3 Byte-based transmission

The physical layer provides *byte-based* communications in both directions, between a managed NE and the head-end. It delivers bytes from one end of the channel to the other end of the channel.

5.4 Byte formats and transmission order

Bytes on both forward and return channels are ten bits in length. They contain one start bit, eight bits of data, and one stop bit. The start bit has binary value '0', and the stop bit has binary value '1'.

Throughout this standard, bits labelled '0' are the least significant bits (LSBs). The LSB of a single byte is always transmitted first following the start bit. Bits labelled '7' are the most

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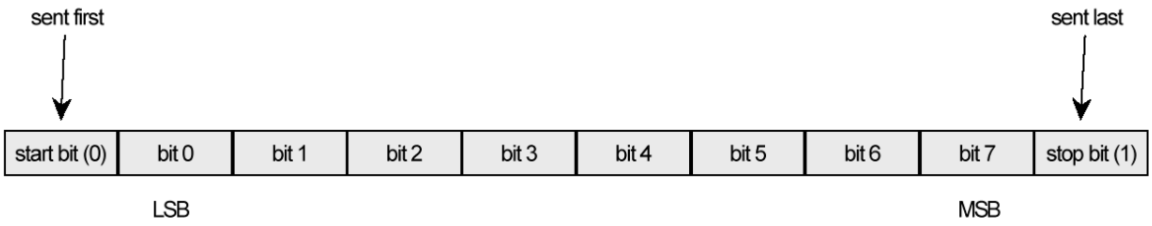
significant bits (MSBs). The MSB of a single byte is always transmitted last followed by the stop bit. The transmission order is summarized in Figure 2.



IEC 2294/03

Figure 2 – Bit transmission order

5.5 Packet-based transmission

Transmission in both forward and return channels is implemented using packets. Transmission on the forward channel is continuous; there is no gap in RF output between packets. Packets are separated by a continuous sequence of bits having value ‘1’, i.e. ‘mark’ tone. The channel is said to ‘rest on mark’ between packets.

Transmission on the return channel is accomplished with burst packets. Packets are separated by periods of silence when the transmitter is turned off. Burst communication is used in the return path of HFC systems because of its ability to solve the many-to-one multiple access characteristic by allowing terminals to ‘take turns’ transmitting.

5.6 Duplex operation

The physical layer implementation in HMS-compliant transponders interfacing to OSP NEs shall support half-duplex operation. There is no requirement for full-duplex operation.

5.7 Forward and return channel specifications

HMS PHY channel RF and modulation specifications for the forward and return communications channels are shown in Table 4. Descriptions of each parameter are provided following that table. Any exceptions to compliance with the specifications in Table 4 will be specifically noted in this document as necessary.

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Table 4 – HMS PHY channel RF and modulation specifications

Item	HE	Transponder
Transmit power level [note 1]	+100 dB(μV) to +111 dB(μV)	+85 dB(μV) to +105 dB(μV)
Transmit power accuracy	±2 dB	±3 dB
Transmit power step size	2 dB	2 dB
Transmitter frequencies [note 2] (reference North American)	48 MHz to 162 MHz, in 6 MHz bands: 1) 48 MHz to 54 MHz 2) 54 MHz to 60 MHz (Channel 2) 3) 60 MHz to 66 MHz (Channel 3) 4) 66 MHz to 72 MHz (Channel 4) 5) 72 MHz to 78 MHz 6) 78 MHz to 84 MHz (~ Channel 5) 7) 84 MHz to 90 MHz (~ Channel 6) 8) 90 MHz to 96 MHz (A-5) 9) 96 MHz to 102 MHz (A-4) 10) 102 MHz to 108 MHz (A-3) 11) 108 MHz to 114 MHz (A-2) 12) 114 MHz to 120 MHz (A-1) 13) 120 MHz to 126 MHz (Channel 14) 14) 126 MHz to 132 MHz (Channel 15) 15) 132 MHz to 138 MHz (Channel 16) 16) 138 MHz to 144 MHz (Channel 17) 17) 144 MHz to 150 MHz (Channel 18) 18) 150 MHz to 156 MHz (Channel 19) 19) 156 MHz to 162 MHz (Channel 20)	5 MHz to 21 MHz, in 4 MHz bands: 1) 5 MHz to 9 MHz 2) 9 MHz to 13 MHz 3) 13 MHz to 17 MHz 4) 17 MHz to 21 MHz
Transmitter tuning range	Fully agile within each of the specified 6 MHz frequency operating ranges	Fully agile within each of the specified 4 MHz frequency operating ranges
Transmitter frequency step size	100 kHz	100 kHz
Transmitter frequency accuracy [note 3]	±10 kHz	±10 kHz
Transmitter cut-off	Not applicable	1 s
Transmitter spurious emissions outside operating channel bandwidth during ON state [note 4]	–65 dB over the forward ~~spectrum~~ path band (referenced to the unmodulated forward carrier)	–55 dB over the full ~~spectrum~~ path band (referenced to the unmodulated forward carrier)
Transmitter conducted spurious emissions outside operating channel bandwidth during OFF state	Not applicable	Single port devices: 25 dB(μV), 5 MHz to 1000 MHz Dual port devices, Transmit port: 25 dB(μV), 5 MHz to 200 MHz 45 dB(μV), 200 MHz to 1000 MHz Dual port devices, Receive port: 45 dB(μV), 5 MHz to 50 MHz 25 dB(μV), 50 MHz to 1000 MHz
Spectral shape	<400 kHz @100 dB/Hz, 48 MHz to 162 MHz (referenced to the unmodulated forward carrier)	<800 kHz @95dB/Hz, 5 MHz to 13 MHz <400 kHz @95dB/Hz, 13 MHz to 21 MHz (referenced to the unmodulated forward carrier)
Transmitter out-of-band noise suppression	C/N of better than –60 dB with a 4 MHz measurement bandwidth, across the forward ~~spectrum~~ path band. (referenced to the unmodulated forward carrier)	
Transmit nominal impedance	75 Ω	75 Ω
Transmit return loss	8 dB or better across forward ~~spectrum~~ path band	12 dB or better
Maximum ramp-up time	Not applicable	100 μs from 10 % to 90 % of peak power
Maximum ramp-down time	Not applicable	100 μs from 90 % to 10 % of peak power
Transmitter front porch time	Not applicable	600 μs to 1,2 ms
Receiver dynamic range	40 dB(μV) to +80 dB(μV)	40 dB(μV) to +80 dB(μV)

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Item	HE	Transponder
Receiver tuning range	Fully agile within each of the specified 4 MHz return frequency operating ranges	Fully agile within each of the specified 6 MHz forward frequency operating ranges
Receiver frequency step size	100 kHz	100 kHz
Receiver *C/(N+I)* (for BER better than 10^{-6})	20 dB	20 dB
Receiver selectivity	CW carrier @ band edge +10 dB higher than received in-band signal power	CW carrier at ±250 kHz from the receiver centre frequency +10 dB higher than received in-band signal power
Receiver nominal impedance	75 Ω	75 Ω
Receiver return loss	12 dB, or better, across return ~~spectrum~~ path band	12 dB or better, see 5.7.21
Transmitter maximum slew rate	8 µs, see 5.7.22	15 µs, see 5.7.22
Transmitter on/off ratio	Not applicable	60 dB
Modulation technique note 5	FSK, Δf = 67 kHz ±10 kHz	FSK, Δf = 67 kHz ±10 kHz
Modulation map note 6)	Mark = $f_c + \Delta f$, space = $f_c - \Delta f$	Mark = $f_c + \Delta f$, space = $f_c - \Delta f$
Bit rate	38,4 kbit/s	38,4 kbit/s
Bit rate accuracy	$\pm 100 \times 10^{-6}$	$\pm 100 \times 10^{-6}$
Transmitter power delta between mark and space	1 dB	2 dB
Transmission duplexing		Half
Transmission mode	Continuous packet transmission. Rests on ‘mark’ between packets	Burst packet transmission. Off between packets
RF connector	Female “F”, outdoor Reference ANSI/SCTE IPS SP 400 or Female “F”, indoor Reference ANSI/SCTE IPS SP 406	Female “F”, outdoor Reference ANSI/SCTE IPS SP 400
Operating temperature range		–40°C to +85°C

NOTE 1 In the NCTEA S-006, NTSC Video carrier level – 10 dB

NOTE 2 In the NCTEA S-006, HE (70,5 MHz) and transponder (46,0 MHz) is used

NOTE 3 In the NCTEA S-006,$\pm 50 \times 10^{-6}$.

NOTE 4 In the NCTEA S-006,-60dBc over.

NOTE 5 In the NCTEA S-006,FSK(HE) and PSK (transponder) is used

NOTE 6 In the NCTEA S-006,mark($f_c - \Delta f$) and space ($f_c + \Delta f$) is used.

5.7.1 Transmit power level

The transmit power level specifies the minimum set of peak power levels supported by the transmitter. It is expressed in dB(µV) and is measured across the full bandwidth of a single channel.

In the Type 3 case where a NE such as a fibre node, amplifier or power supply, has built-in transponder functionality, the equipment is exempted from complying with this particular parameter. In such a case, there is no practical way to measure the transmitted power of the transponder, only the power seen at the NE’s output, which may be affected by coupling losses internal to the NE. Even though the equipment is exempt from compliance in this particular case, the NE vendor shall supply a clear specification of the equipment’s transmit power levels at the NE’s output so that it can be properly engineered into the network.

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5.7.2 Transmit power accuracy

Transmit power accuracy is the accuracy of the actual transmitted power relative to the provisioned value for transmit power. Transmit power accuracy is valid over a temperature range defined by the operating temperature range.

5.7.3 Transmit power step size

Transmit power step size specifies the minimum change in the provisioned output power level that the transmitter must support. When changing the provisioned output power level by the transmit power step size, the actual transmit power level shall nominally respond by the transmit power step size for each step over the entire transmitter power level range.

5.7.4 Transmitter frequencies

The transmitter frequencies specify the minimum set of frequencies on which the centre frequency of the transmitter may be placed. On the forward channel, the centre frequencies are segmented into 6 MHz ranges. The return channel is segmented into 4 MHz ranges. At a minimum, vendors must support one 6 MHz forward band and one 4 MHz return band.

Both the forward and return channels require the transmitter to be dynamically agile over the specified set of frequencies. A dynamically agile system allows the user to select and set the transmission frequency in real-time while the product is in use. The specific mechanism used to implement agility is left to the vendor.

5.7.5 Transmitter frequency step size

This is the allowed carrier frequency increment for tuning purposes. This does not imply that carriers may be placed one step apart.

5.7.6 Transmitter frequency accuracy

The accuracy of the actual transmitted centre frequency relative to the provisioned value for that frequency. The output frequency accuracy is valid over a temperature range specified by the operating temperature range specification, over the full frequency range of the transmitter and over the full range of powers.

5.7.7 Transmitter conducted spurious

Transmitter conducted spurious refers to conducted emissions outside of the operating channel bandwidth.

5.7.8 Spectral shape

Transmitted power outside of the channel width shall be attenuated according to the spectral emission and spurious tone specifications. The channel width is the spectral width of the channel.

5.7.9 Transmitter out-of-band noise suppression

This is a carrier-to-noise specification covering noise outside of the transmit channel and refers to the total noise power as measured with a 4 MHz measurement bandwidth.

5.7.10 Transmit nominal impedance

The transmit nominal impedance is the impedance into which the transmitter is designed to launch.

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5.7.11 Transmit return loss

The transmit return loss is the ratio of the transmitted signal power to the reflected signal power at the transmitter. The transmit return loss shall meet or exceed the specification at all frequencies in the measurement range.

Head-end Element (HE)

The transmit return loss shall apply over the forward ~~spectrum~~ path band.

Transponder

Dual port Return loss specification applies to the RF transmit port of dual port devices in the frequency range defined by the return ~~spectrum~~ path band.

Single port Return loss specification applies to the common RF port of single port devices in the frequency range defined by the full ~~spectrum~~ path band.

In the Type 3 case where a NE such as a fibre node, amplifier or power supply, has built-in transponder functionality, the equipment is exempted from complying with this particular parameter. In such a case, there is no practical way to measure transmitter return loss of the transponder, only the return loss seen at the NE. However, the embedded transponder shall not degrade the overall transmit return loss at the NE. Even though the equipment is exempt from compliance in this particular case, the vendor shall still supply a clear specification of the equipment's transmit return loss so that it can be properly engineered into the network.

5.7.12 Maximum ramp-up time

The maximum ramp-up time is the maximum time the transmitter can take to go from 10 % of full output peak power to 90 % of full output peak power. This quantity is important because of the burst transmission nature of the channels involved.

5.7.13 Maximum ramp-down time

The maximum ramp-down time is the maximum time the transmitter can take to go from 90 % of full output peak power to 10 % of full output peak power. This quantity is important because of the burst transmission nature of the channels involved.

5.7.14 Transmitter front porch time

Front porch time specifies the time following ramp-up but before start of data transmission. During the front porch time the transmitter rests on 'mark'.

5.7.15 Receive power dynamic range

The receive power dynamic range is the range of received power over which the receiver is guaranteed to meet bit error rate (BER) and carrier to noise-plus-interference (C/(N+I)) specifications. (see 5.7.18). It is expressed in dB(μV).

In the Type 3 case where an NE such as a fibre node, amplifier or power supply, has built-in transponder functionality, the equipment is exempted from complying with this particular parameter. In such a case, there is no practical way to measure the receiver power range of the transponder, only the power seen at the managed NE's RF input port which may not equal the power seen by the internal transponder because of coupling losses internal to the network element. Even though the equipment is exempt from compliance in this particular case, the vendor must still supply a clear specification of the equipment's receive power range at the network element's input so that it can be properly engineered into the network.

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5.7.16 Receive tuning range

The receiver frequencies specify the minimum set of frequencies on which the centre frequency of the receiver can be placed. On the forward channel, the centre frequencies are segmented into 6 MHz ranges. The return channel is segmented into 4 MHz ranges. At a minimum, vendors shall support one 6 MHz forward band and one 4 MHz return band.

Both the forward and return channels require the receiver to be the receiver frequency in real-time while the product is in use. The specific mechanism used to implement agility is left to the vendor.

5.7.17 Receiver frequency step size

This is the allowed carrier frequency increment for tuning purposes. This does not imply that carriers may be placed one step apart.

5.7.18 Receive C/(N+I)

The receive C/(N+I) is the minimum ratio of the received signal power to the received noise + interference power at the receiver input, measured across the full channel frequency width, required to achieve the specified BER. It is valid across the entire dynamic range of the receiver and over the temperature range specified for the equipment. It is also valid regardless of what other signals are present on the cable plant, as long as they meet the selectivity specification described in 5.7.19. It is measured only in the presence of Gaussian noise. Impulse noise is not included when measuring the receive C/(N+I).

5.7.19 Receiver selectivity

Selectivity measures the receiver's ability to reject a nearby carrier. It is the ratio of the power of an interfering continuous wave (CW) carrier to the received in-band power. The interfering carrier is located at a specific frequency relative to the receiver's centre frequency. The receiver must meet the C/(N+I) specification given in 5.7.18 in the presence of any interfering carrier, which meets the selectivity criteria.

5.7.20 Receive nominal impedance

The impedance for which the receiver is designed.

5.7.21 Receive return loss

The receive return loss is the ratio of the received signal power to the reflected signal power at the receiver measured over the specified frequency range.

Head-end Element (HE)

The receive return loss applies over the return ~~spectrum~~ path band.

Transponder

The receive return loss applies as follows:

Dual port The return loss specification applies to the RF receive port of dual port devices in the frequency range defined by the forward ~~spectrum~~ path band.

Single port The return loss specification applies to the common RF port of single port devices in the frequency range defined by the full ~~spectrum~~ path band.

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In the Type 3 case where a NE such as a fibre node, amplifier or power supply, has built-in transponder functionality, the equipment is exempted from complying with this particular parameter. In such a case, there is no practical way to measure the receiver return loss of the transponder, only the return loss seen at the NE. However, the embedded transponder shall not degrade the overall receive return loss at the NE. Even though the equipment is exempt from compliance in this particular case, the vendor shall still supply a clear specification of the equipment's receive return loss so that it can be properly engineered into the network.

The network engineer may need to add loss at the transponder's coupler in order to achieve a return loss that is sufficient to avoid impacting other services offered in the band.

5.7.22 Transmitter slew rate

The slew rate describes how quickly the transmitter moves from transmitting a logical '0' to a logical '1' and vice versa. For both the forward and return channels, the transmitter's transition time between binary states must be controlled to ensure that the signal frequency is within 13,4 kHz (= $2\Delta f \times 10$ %), for a $\Delta f = 67$ kHz, of the initial and final values of $+\Delta f$ or $-\Delta f$, within the specified time.

5.7.23 Transmitter on/off ratio

The transmitter on/off ratio is the ratio between the 'on' transmitted power and the 'off' transmitted power.

5.7.24 Modulation technique

The modulation technique is the method by which digital information is impressed into the analog channel. In this case, the modulation is binary frequency shift keying (FSK) with the two shift tones at $\pm\Delta f$ from the centre frequency. A logical '1' is mapped to the upper of the two shift frequencies and a logical '0' is mapped to the lower of the two shift frequencies. The notation f_c denotes the centre frequency of the channel and Δf denotes the FSK frequency shift. The 'mark' (logical '1') frequency is $f_1 = f_c + \Delta f$ and the 'space' (logical '0') frequency is $f_0 = f_c - \Delta f$.

5.7.25 Bit rate

The bit rate is the nominal transmission rate for the channel.

5.7.26 Bit rate accuracy

The bit rate accuracy is the maximum deviation from the provisioned value of the bit rate. It is valid over the full temperature range specified for the equipment.

5.7.27 Transmitter power delta between 'mark' and 'space'

The transmitter power delta between 'mark' and 'space' is the difference between the peak power of the 'mark' signal and the peak power of the 'space' signal.

5.7.28 Transmission duplexing

This specifies whether a device supports full-duplex or half-duplex operation.

5.7.29 Transmission mode

The transmission mode describes the overall mode in which the physical layer transmits data. Bytes on both the forward and return channels are transmitted asynchronously. Both the forward and return channels are packet-based; however, they differ in how they handle the gaps between packets. On the forward channel, the transmitter is continuously on. It rests on

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‘mark’ between packets. In contrast, the return channel transmitter turns off between packets. It does this to support multiple access on the many-to-one return channel.

5.7.30 RF connector

This specifies the type of RF connector that shall be supported. Support for an RF connector option depends on the transponder type as defined in Table 1.

5.7.31 Operating temperature range

This specifies the minimum set of temperatures over which HMS compliant transponders shall operate and meet this specification.

5.8 Media access control layer interface

The PHY layer delivers bytes to and from the Media Access Control (MAC) Layer based on its detection of the incoming signal. The exact method for delivering these bytes is left to the vendor. The physical layer could also deliver an indication of ‘insufficient power’ to indicate periods during which the quality of the received signal is too low to reliably detect binary 0’s and 1’s. The MAC layer can use this information to help it determine the beginning and end of packets. The exact method for declaring ‘insufficient power’ is left to the vendor.

5.9 RF cut-off

RF cut-off is required on the return channel to shut down transponders that have failed with their transmitter ON. A transponder in this state is often referred to as a ‘babbler’. RF cutoff shall be invoked automatically to ensure a transponder shall never leave its transmitter ON for more than 1 s after it has been enabled or when a message is received from the head-end indicating that the RF output should be cut off. The cut-off time shall be such that, after taking into account timer inaccuracy, the RF transmitter shall be cut off within 1 s after it has been enabled. The cut-off mechanism should protect against all reasonably likely failures including a microprocessor failure. When cut off, the transponder’s RF output power should meet the on/off power specification in 5.7.23. RF cut-off is not required on the forward channel.

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Cable networks for television signals, sound signals and interactive services – Part 7-1: Hybrid Fibre Coax Outside Plant status monitoring – Physical (PHY) Layer Specification

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CABLE NETWORKS FOR TELEVISION SIGNALS, SOUND SIGNALS AND INTERACTIVE SERVICES –

Part 7-1: Hybrid Fibre Coax Outside Plant status monitoring – Physical (PHY) layer specification

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This Consolidated version of IEC 60728-7-1 bears the edition number 1.1. It consists of the first edition (2003-10) [documents 100/576/CDV and 100/683/RVC] and its amendment 1 (2015-04) [documents 100/2417/FDIS and 100/2481/RVD]. The technical content is identical to the base edition and its amendment.

This Final version does not show where the technical content is modified by amendment 1. A separate Redline version with all changes highlighted is available in this publication.

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International Standard IEC 60728-7-1 has been prepared by technical area 5: Cable networks for television signals, sound signals and interactive services, of IEC technical committee 100: Audio, video and multimedia systems and equipment.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

The following differences exist in some countries:

The Japanese *de facto* standard (NCTEA S-006) concerning requirements for the HFC outside plant management, which was published in 1995, has already been available in Japan. The purpose of this standard is to support the design and implementation of interoperable management systems for HFC cable networks used in Japan. (see Table 4)

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INTRODUCTION

Standards and other deliverables of the IEC 60728 series deal with cable networks including equipment and associated methods of measurement for headend reception, processing and distribution of television and sound signals and for processing, interfacing and transmitting all kinds of data signals for interactive services using all applicable transmission media. These signals are typically transmitted in networks by frequency-multiplexing techniques.

This includes for instance

- regional and local broadband cable networks,
- extended satellite and terrestrial television distribution systems,
- individual satellite and terrestrial television receiving systems,

and all kinds of equipment, systems and installations used in such cable networks, distribution and receiving systems.

The extent of this standardization work is from the antennas and/or special signal source inputs to the headend or other interface points to the network up to the terminal input of the customer premises equipment.

The standardization work will consider coexistence with users of the RF spectrum in wired and wireless transmission systems.

The standardization of any user terminals (i.e. tuners, receivers, decoders, multimedia terminals, etc.) as well as of any coaxial and optical cables and accessories thereof is excluded.

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CABLE NETWORKS FOR TELEVISION SIGNALS, SOUND SIGNALS AND INTERACTIVE SERVICES –

Part 7-1: Hybrid Fibre Coax Outside Plant status monitoring – Physical (PHY) layer specification

1 Scope

This part of IEC 60728 specifies requirements for The Hybrid Fibre Coax (HFC) Outside Plant (OSP) Physical (PHY) Layer Specification and is part of the series of specifications developed by the Hybrid Management Sub-Layer (HMS) subcommittee under the SCTE. The purpose of the HMS specification is to support the design and implementation of interoperable management systems for evolving HFC cable networks. The HMS Physical (PHY) Layer Specification describes the physical layer portion of the protocol stack used for communication between HMS-compliant transponders interfacing to managed outside plant network elements (NE) and a centralized head-end element (HE).

This standard describes the PHY layer requirements that must be implemented by all *Type 2* and *Type 3* compliant OSP HMS transponders on the HFC plant and the controlling equipment in the head-end. Any exceptions to compliance with this standard will be specifically noted herein as necessary. Refer to Table 1 for a full definition of the type classifications.

Electromagnetic Compatibility (EMC) is not specified in this standard and is left to the vendor to ensure compliance with local EMC regulatory requirements. Other than operating temperature, physical parameters such as shock, vibration, humidity, etc., are also not specified and left to the vendor’s discretion.

Transponder type classifications referenced within the HMS series of standards are defined in Table 1.

Table 1 – Transponder type classifications

Type	Description	Application
Type 0	Refers to legacy transponder equipment, which is incapable of supporting the HMS specifications	This transponder interfaces with legacy network equipment through proprietary means. This transponder could be managed through the same management applications as the other types through proxies or other means at the head-end
Type 1	Refers to stand-alone transponder equipment (legacy or new) which can be upgraded to support the HMS specifications	This transponder interfaces with legacy network equipment through proprietary means. Type 1 is a standards-compliant transponder (either manufactured to the standard or upgraded) that connects to legacy network equipment via a proprietary interface
Type 2	Refers to a stand-alone, HMS-compliant transponder	This transponder interfaces with network equipment designed to support the electrical and physical specifications defined in the HMS standards. It can be factory or field-installed. Its RF connection is independent of the monitored NE
Type 3	Refers to a stand-alone or embedded, HMS-compliant transponder	This transponder interfaces with network equipment designed to support the electrical specifications defined in the HMS standards. It may or may not support the physical specifications defined in the HMS standards. It can be factory-installed. It may or may not be field-installed. Its RF connection is through the monitored NE

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2 Normative references

None.

3 Terms, definitions and abbreviations

For the purposes of this document, the following terms and definitions apply.

3.1
forward path band
continuous set of frequencies in HFC cable systems with a lower edge of between 48 MHz and 87,5 MHz, depending on the particular geographical area, and an upper edge that is typically in the range of 300 MHz to 1 000 MHz depending on implementation

Note 1 to entry: Due to different channel spacing plans in use, this upper frequency limit may not be exactly 1 000 MHz, but some megahertz higher, e.g. 1 002 MHz or 1 006 MHz. The notation 1 000 MHz in this standard is intended to include such small deviations.

3.2
full path band
combination of forward path band and return path band in HFC cable systems excluding any guard band

3.3
guard band
unused frequency band between the upper edge of the usable return path band and the lower edge of the usable forward path band in HFC cable systems

3.4
network element (NE)
active element in the outside plant that is capable of receiving commands from a head-end element (HE) in the head-end and, as necessary, providing status information and alarms back to the HE

3.5
open system interconnection (OSI)
framework of International Organization for Standardization (ISO) standards for communication between multi-vendor systems that organizes the communication process into seven different categories that are placed in a layered sequence based on the relationship to the user. Each layer uses the layer immediately below it and provides services to the layer above. Layers 7 through 4 deal with end-to-end communication between the message source and destination, and layers 3 through 1 deal with network functions

3.6
physical (PHY) layer
layer 1 in the Open System Interconnection (OSI) architecture; the layer that provides services to transmit bits or groups of bits over a transmission link between open systems and which entails electrical, mechanical and handshaking procedures

3.7
return path band
continuous set of frequencies in HFC cable systems with a lower edge of 5 MHz and an upper edge that is typically in the range of 42 MHz to 65 MHz depending on the particular geographical area

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3.8
transponder
device in the outside plant that interfaces to outside plant NEs and relays status and alarm information to the HE. It can interface with an active NE via an arrangement of parallel analogue, parallel digital and serial ports

3.9
un-modulated carrier
carrier resting on the ‘mark’ frequency rather than on the channel’s centre frequency

3.10 Abbreviated terms

ANSI	American National Standards Institute
BER	Bit Error Rate
C/R	Carrier-to-Noise Ratio
C/(N+I)	Carrier to Noise-plus-Interference Ratio
CW	Continuous Wave
EMC	Electromagnetic Compatibility
FSK	Frequency Shift Keying
HE	Head-end Element
HFC	Hybrid Fibre Coax
HMS	Hybrid Management Sub-Layer
LSB	Least Significant Bit
MSB	Most Significant Bit
NE	Network Element
MAC	Media Access Control
OSP	Outside Plant
PHY	Physical
RF	Radio Frequency
SCTE	Society of Cable Telecommunications Engineers

4 HMS reference architecture forward and return channel specifications

The reference architecture for the HMS series of specifications is illustrated in Figure 1.

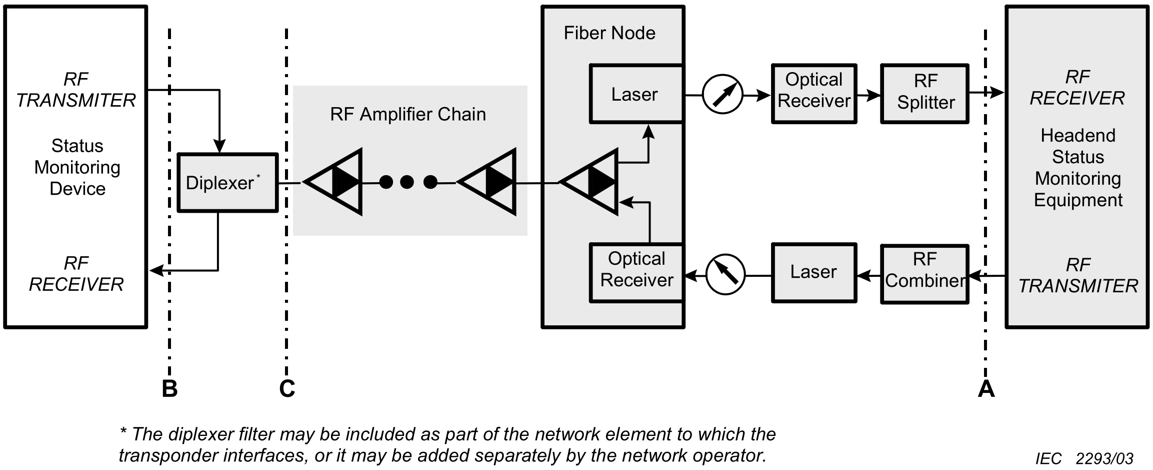

Figure 1 – HMS reference architecture diagram

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All quantities relating to forward channel transmission or reverse channel reception are measured at point A in Figure 1. All quantities relating to forward channel reception or reverse channel transmission are measured at point B for two-port devices and point C for single port devices as shown in Figure 1.

4.1 HMS specification documents

A list of documents in the HMS specifications family is provided in Table 2.

Table 2 – HMS document family

HMS notation	Title
SCTE HMS PHY	HMS Outside Plant Status Monitoring – Physical (PHY) Layer Specification
SCTE HMS MAC	HMS Outside Plant Status Monitoring – Media Access Control (MAC) Layer Specification
SCTE HMS PSTIB	HMS Outside Plant Status Monitoring – Power Supply to Transponder Interface Bus (PSTIB) Specification
SCTE HMS ALARMS MIB	HMS Alarms Management Information Base
SCTE HMS COMMON MIB	HMS Common Management Information Base
SCTE HMS FIBERNODE MIB	HMS Fiber Node Management Information Base
SCTE HMS PROPERTY MIB	HMS Alarm Property Management Information Base
SCTE HMS PS MIB	HMS Power Supply Management Information Base
SCTE ROOT MIB	SCTE Root Management Information Base
SCTE HMS GEN MIB	HMS Power Supply Generator Management Information Base
SCTE HMS TIB MIB	HMS Transponder Interface Bus Management Information Base
SCTE HMS DOWNLOAD MIB	HMS Transponder Firmware Download Management Information Base
SCTE HMS TREE MIB	HMS Root Object Identifiers Management Information Base

4.2 Functional assumptions

4.2.1 Forward path band and return path band

The forward path band in HFC cable systems refers to the continuous set of frequencies with a lower edge of between 48 MHz and 87,5 MHz, depending on the particular geographical area, and an upper edge that is typically in the range of 300 MHz to 1 000 MHz depending on implementation. Analogue television signals in 6 MHz or 8 MHz channels are assumed to be present on the forward path band as well as other narrowband and wideband digital signals.

The return path band in HFC cable systems refers to the pass band of frequencies with a lower edge of 5 MHz and an upper edge that is typically in the range of 42 MHz to 65 MHz depending on the particular geographical area. Narrowband and wideband digital signals may be present on the return path band as well as analogue television signals in 6 MHz or 8 MHz channels.

The full path band in HFC cable systems refers to the combined forward and return path bands and excludes any guard band. The guard band refers to the unused frequency band between the upper edge of the usable return path band and the lower edge of the usable forward path band. Specific limits on forward and return path band for various geographical areas are detailed in Table 3.

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Table 3 – Spectral limits by geographical area (North America and Europe)

Geography	Return path band		Forward path band	
	Minimum frequency	Guard band lower limit	Guard band upper limit	Maximum frequency
North America	5 MHz	42 MHz	48 MHz	1 000 GHz
Europe 1	5 MHz	30 MHz	47 MHz	862 MHz
Europe 2	5 MHz	50 MHz	70 MHz	1 000 MHz
Europe 3	5 MHz	65 MHz	87,5 MHz	1 000 MHz

4.2.2 Transmission levels

The nominal level of the forward path band HMS carrier(s) is targeted to be no higher than –10 dB relative to analogue video nominal carrier levels. The nominal power level of the return path band HMS carrier(s) will be as low as possible to achieve the required margin above noise and interference. Uniform power loading per unit bandwidth is commonly followed in setting signal levels on the return path band, with specific levels established by the cable network operator to achieve the required carrier-to-noise and carrier-to-interference ratios.

5 Physical layer specification

This clause describes version 1.0 of the HMS PHY layer specification. The PHY layer describes rules that govern the transmission of bytes from one device to another. The specific requirements of the HMS PHY layer are detailed in this clause.

5.1 Separate forward and return channels

The one-way communication channel from the HE to a managed OSP NE is referred to as the *forward* channel. The one-way communication channel from a managed OSP NE to the HE is referred to as the *return* channel. Both the forward and the return channels are placed on specific centre frequencies. The forward and return channels’ centre frequencies are different. Since the NEs only listen to the forward channel, they cannot listen to return channel transmissions from other NEs. This channel separation is a result of the sub-band split between the forward and return portions of the typical HFC plant spectrum.

5.2 Single forward and return path channels

To keep management of carrier frequencies simple, each HMS-based status monitoring system has a single forward channel and a single return channel. This does not preclude the use of multiple monitoring systems, each with its own individual forward and return RF channels.

5.3 Byte-based transmission

The physical layer provides *byte-based* communications in both directions, between a managed NE and the head-end. It delivers bytes from one end of the channel to the other end of the channel.

5.4 Byte formats and transmission order

Bytes on both forward and return channels are ten bits in length. They contain one start bit, eight bits of data, and one stop bit. The start bit has binary value ‘0’, and the stop bit has binary value ‘1’.

Throughout this standard, bits labelled ‘0’ are the least significant bits (LSBs). The LSB of a single byte is always transmitted first following the start bit. Bits labelled ‘7’ are the most

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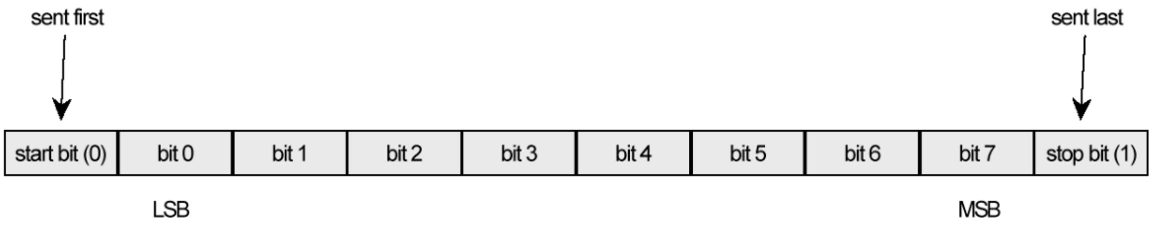
significant bits (MSBs). The MSB of a single byte is always transmitted last followed by the stop bit. The transmission order is summarized in Figure 2.



IEC 2294/03

Figure 2 – Bit transmission order

5.5 Packet-based transmission

Transmission in both forward and return channels is implemented using packets. Transmission on the forward channel is continuous; there is no gap in RF output between packets. Packets are separated by a continuous sequence of bits having value ‘1’, i.e. ‘mark’ tone. The channel is said to ‘rest on mark’ between packets.

Transmission on the return channel is accomplished with burst packets. Packets are separated by periods of silence when the transmitter is turned off. Burst communication is used in the return path of HFC systems because of its ability to solve the many-to-one multiple access characteristic by allowing terminals to ‘take turns’ transmitting.

5.6 Duplex operation

The physical layer implementation in HMS-compliant transponders interfacing to OSP NEs shall support half-duplex operation. There is no requirement for full-duplex operation.

5.7 Forward and return channel specifications

HMS PHY channel RF and modulation specifications for the forward and return communications channels are shown in Table 4. Descriptions of each parameter are provided following that table. Any exceptions to compliance with the specifications in Table 4 will be specifically noted in this document as necessary.

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Table 4 – HMS PHY channel RF and modulation specifications

Item	HE	Transponder
Transmit power level note 1	+100 dB(μV) to +111 dB(μV)	+85 dB(μV) to +105 dB(μV)
Transmit power accuracy	±2 dB	±3 dB
Transmit power step size	2 dB	2 dB
Transmitter frequencies note 2 (reference North American)	48 MHz to 162 MHz, in 6 MHz bands: 1) 48 MHz to 54 MHz 2) 54 MHz to 60 MHz (Channel 2) 3) 60 MHz to 66 MHz (Channel 3) 4) 66 MHz to 72 MHz (Channel 4) 5) 72 MHz to 78 MHz 6) 78 MHz to 84 MHz (~ Channel 5) 7) 84 MHz to 90 MHz (~ Channel 6) 8) 90 MHz to 96 MHz (A-5) 9) 96 MHz to 102 MHz (A-4) 10) 102 MHz to 108 MHz (A-3) 11) 108 MHz to 114 MHz (A-2) 12) 114 MHz to 120 MHz (A-1) 13) 120 MHz to 126 MHz (Channel 14) 14) 126 MHz to 132 MHz (Channel 15) 15) 132 MHz to 138 MHz (Channel 16) 16) 138 MHz to 144 MHz (Channel 17) 17) 144 MHz to 150 MHz (Channel 18) 18) 150 MHz to 156 MHz (Channel 19) 19) 156 MHz to 162 MHz (Channel 20)	5 MHz to 21 MHz, in 4 MHz bands: 1) 5 MHz to 9 MHz 2) 9 MHz to 13 MHz 3) 13 MHz to 17 MHz 4) 17 MHz to 21 MHz
Transmitter tuning range	Fully agile within each of the specified 6 MHz frequency operating ranges	Fully agile within each of the specified 4 MHz frequency operating ranges
Transmitter frequency step size	100 kHz	100 kHz
Transmitter frequency accuracy note 3	±10 kHz	±10 kHz
Transmitter cut-off	Not applicable	1 s
Transmitter spurious emissions outside operating channel bandwidth during ON state note 4	–65 dB over the forward path band (referenced to the unmodulated forward carrier)	–55 dB over the full path band (referenced to the unmodulated forward carrier)
Transmitter conducted spurious emissions outside operating channel bandwidth during OFF state	Not applicable	Single port devices: 25 dB(μV), 5 MHz to 1000 MHz Dual port devices, Transmit port: 25 dB(μV), 5 MHz to 200 MHz 45 dB(μV), 200 MHz to 1000 MHz Dual port devices, Receive port: 45 dB(μV), 5 MHz to 50 MHz 25 dB(μV), 50 MHz to 1000 MHz
Spectral shape	<400 kHz @100 dB/Hz, 48 MHz to 162 MHz (referenced to the unmodulated forward carrier)	<800 kHz @95dB/Hz, 5 MHz to 13 MHz <400 kHz @95dB/Hz, 13 MHz to 21 MHz (referenced to the unmodulated forward carrier)
Transmitter out-of-band noise suppression	C/N of better than –60 dB with a 4 MHz measurement bandwidth, across the forward path band. (referenced to the unmodulated forward carrier)	
Transmit nominal impedance	75 Ω	75 Ω
Transmit return loss	8 dB or better across forward path band	12 dB or better
Maximum ramp-up time	Not applicable	100 μs from 10 % to 90 % of peak power
Maximum ramp-down time	Not applicable	100 μs from 90 % to 10 % of peak power
Transmitter front porch time	Not applicable	600 μs to 1,2 ms
Receiver dynamic range	40 dB(μV) to +80 dB(μV)	40 dB(μV) to +80 dB(μV)

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Item	HE	Transponder
Receiver tuning range	Fully agile within each of the specified 4 MHz return frequency operating ranges	Fully agile within each of the specified 6 MHz forward frequency operating ranges
Receiver frequency step size	100 kHz	100 kHz
Receiver *C/(N+I)* (for BER better than 10^{-6})	20 dB	20 dB
Receiver selectivity	CW carrier @ band edge +10 dB higher than received in-band signal power	CW carrier at ±250 kHz from the receiver centre frequency +10 dB higher than received in-band signal power
Receiver nominal impedance	75 Ω	75 Ω
Receiver return loss	12 dB, or better, across return path band	12 dB or better, see 5.7.21
Transmitter maximum slew rate	8 μs, see 5.7.22	15 μs, see 5.7.22
Transmitter on/off ratio	Not applicable	60 dB
Modulation technique note 5	FSK, Δf = 67 kHz ±10 kHz	FSK, Δf = 67 kHz ±10 kHz
Modulation map note 6)	Mark = $f_c + \Delta f$, space = $f_c - \Delta f$	Mark = $f_c + \Delta f$, space = $f_c - \Delta f$
Bit rate	38,4 kbit/s	38,4 kbit/s
Bit rate accuracy	$\pm 100 \times 10^{-6}$	$\pm 100 \times 10^{-6}$
Transmitter power delta between mark and space	1 dB	2 dB
Transmission duplexing		Half
Transmission mode	Continuous packet transmission. Rests on ‘mark’ between packets	Burst packet transmission. Off between packets
RF connector	Female “F”, outdoor Reference ANSI/SCTE IPS SP 400 or Female “F”, indoor Reference ANSI/SCTE IPS SP 406	Female “F”, outdoor Reference ANSI/SCTE IPS SP 400
Operating temperature range		–40°C to +85°C
NOTE 1 In the NCTEA S-006, NTSC Video carrier level – 10 dB NOTE 2 In the NCTEA S-006, HE (70,5 MHz) and transponder (46,0 MHz) is used NOTE 3 In the NCTEA S-006,$\pm 50 \times 10^{-6}$. NOTE 4 In the NCTEA S-006,-60dBc over. NOTE 5 In the NCTEA S-006,FSK(HE) and PSK (transponder) is used NOTE 6 In the NCTEA S-006,mark($f_c - \Delta f$) and space ($f_c + \Delta f$) is used.		

5.7.1 Transmit power level

The transmit power level specifies the minimum set of peak power levels supported by the transmitter. It is expressed in dB(μV) and is measured across the full bandwidth of a single channel.

In the Type 3 case where a NE such as a fibre node, amplifier or power supply, has built-in transponder functionality, the equipment is exempted from complying with this particular parameter. In such a case, there is no practical way to measure the transmitted power of the transponder, only the power seen at the NE’s output, which may be affected by coupling losses internal to the NE. Even though the equipment is exempt from compliance in this particular case, the NE vendor shall supply a clear specification of the equipment’s transmit power levels at the NE’s output so that it can be properly engineered into the network.

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5.7.2 Transmit power accuracy

Transmit power accuracy is the accuracy of the actual transmitted power relative to the provisioned value for transmit power. Transmit power accuracy is valid over a temperature range defined by the operating temperature range.

5.7.3 Transmit power step size

Transmit power step size specifies the minimum change in the provisioned output power level that the transmitter must support. When changing the provisioned output power level by the transmit power step size, the actual transmit power level shall nominally respond by the transmit power step size for each step over the entire transmitter power level range.

5.7.4 Transmitter frequencies

The transmitter frequencies specify the minimum set of frequencies on which the centre frequency of the transmitter may be placed. On the forward channel, the centre frequencies are segmented into 6 MHz ranges. The return channel is segmented into 4 MHz ranges. At a minimum, vendors must support one 6 MHz forward band and one 4 MHz return band.

Both the forward and return channels require the transmitter to be dynamically agile over the specified set of frequencies. A dynamically agile system allows the user to select and set the transmission frequency in real-time while the product is in use. The specific mechanism used to implement agility is left to the vendor.

5.7.5 Transmitter frequency step size

This is the allowed carrier frequency increment for tuning purposes. This does not imply that carriers may be placed one step apart.

5.7.6 Transmitter frequency accuracy

The accuracy of the actual transmitted centre frequency relative to the provisioned value for that frequency. The output frequency accuracy is valid over a temperature range specified by the operating temperature range specification, over the full frequency range of the transmitter and over the full range of powers.

5.7.7 Transmitter conducted spurious

Transmitter conducted spurious refers to conducted emissions outside of the operating channel bandwidth.

5.7.8 Spectral shape

Transmitted power outside of the channel width shall be attenuated according to the spectral emission and spurious tone specifications. The channel width is the spectral width of the channel.

5.7.9 Transmitter out-of-band noise suppression

This is a carrier-to-noise specification covering noise outside of the transmit channel and refers to the total noise power as measured with a 4 MHz measurement bandwidth.

5.7.10 Transmit nominal impedance

The transmit nominal impedance is the impedance into which the transmitter is designed to launch.

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5.7.11 Transmit return loss

The transmit return loss is the ratio of the transmitted signal power to the reflected signal power at the transmitter. The transmit return loss shall meet or exceed the specification at all frequencies in the measurement range.

Head-end Element (HE)

The transmit return loss shall apply over the forward path band.

Transponder

Dual port Return loss specification applies to the RF transmit port of dual port devices in the frequency range defined by the return path band.

Single port Return loss specification applies to the common RF port of single port devices in the frequency range defined by the full path band.

In the Type 3 case where a NE such as a fibre node, amplifier or power supply, has built-in transponder functionality, the equipment is exempted from complying with this particular parameter. In such a case, there is no practical way to measure transmitter return loss of the transponder, only the return loss seen at the NE. However, the embedded transponder shall not degrade the overall transmit return loss at the NE. Even though the equipment is exempt from compliance in this particular case, the vendor shall still supply a clear specification of the equipment’s transmit return loss so that it can be properly engineered into the network.

5.7.12 Maximum ramp-up time

The maximum ramp-up time is the maximum time the transmitter can take to go from 10 % of full output peak power to 90 % of full output peak power. This quantity is important because of the burst transmission nature of the channels involved.

5.7.13 Maximum ramp-down time

The maximum ramp-down time is the maximum time the transmitter can take to go from 90 % of full output peak power to 10 % of full output peak power. This quantity is important because of the burst transmission nature of the channels involved.

5.7.14 Transmitter front porch time

Front porch time specifies the time following ramp-up but before start of data transmission. During the front porch time the transmitter rests on ‘mark’.

5.7.15 Receive power dynamic range

The receive power dynamic range is the range of received power over which the receiver is guaranteed to meet bit error rate (BER) and carrier to noise-plus-interference (C/(N+I)) specifications. (see 5.7.18). It is expressed in dB(μV).

In the Type 3 case where an NE such as a fibre node, amplifier or power supply, has built-in transponder functionality, the equipment is exempted from complying with this particular parameter. In such a case, there is no practical way to measure the receiver power range of the transponder, only the power seen at the managed NE’s RF input port which may not equal the power seen by the internal transponder because of coupling losses internal to the network element. Even though the equipment is exempt from compliance in this particular case, the vendor must still supply a clear specification of the equipment’s receive power range at the network element’s input so that it can be properly engineered into the network.

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5.7.16 Receive tuning range

The receiver frequencies specify the minimum set of frequencies on which the centre frequency of the receiver can be placed. On the forward channel, the centre frequencies are segmented into 6 MHz ranges. The return channel is segmented into 4 MHz ranges. At a minimum, vendors shall support one 6 MHz forward band and one 4 MHz return band.

Both the forward and return channels require the receiver to be the receiver frequency in real-time while the product is in use. The specific mechanism used to implement agility is left to the vendor.

5.7.17 Receiver frequency step size

This is the allowed carrier frequency increment for tuning purposes. This does not imply that carriers may be placed one step apart.

5.7.18 Receive C/(N+I)

The receive C/(N+I) is the minimum ratio of the received signal power to the received noise + interference power at the receiver input, measured across the full channel frequency width, required to achieve the specified BER. It is valid across the entire dynamic range of the receiver and over the temperature range specified for the equipment. It is also valid regardless of what other signals are present on the cable plant, as long as they meet the selectivity specification described in 5.7.19. It is measured only in the presence of Gaussian noise. Impulse noise is not included when measuring the receive C/(N+I).

5.7.19 Receiver selectivity

Selectivity measures the receiver's ability to reject a nearby carrier. It is the ratio of the power of an interfering continuous wave (CW) carrier to the received in-band power. The interfering carrier is located at a specific frequency relative to the receiver's centre frequency. The receiver must meet the C/(N+I) specification given in 5.7.18 in the presence of any interfering carrier, which meets the selectivity criteria.

5.7.20 Receive nominal impedance

The impedance for which the receiver is designed.

5.7.21 Receive return loss

The receive return loss is the ratio of the received signal power to the reflected signal power at the receiver measured over the specified frequency range.

Head-end Element (HE)

The receive return loss applies over the return path band.

Transponder

The receive return loss applies as follows:

Dual port The return loss specification applies to the RF receive port of dual port devices in the frequency range defined by the forward path band.

Single port The return loss specification applies to the common RF port of single port devices in the frequency range defined by the full path band.

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In the Type 3 case where a NE such as a fibre node, amplifier or power supply, has built-in transponder functionality, the equipment is exempted from complying with this particular parameter. In such a case, there is no practical way to measure the receiver return loss of the transponder, only the return loss seen at the NE. However, the embedded transponder shall not degrade the overall receive return loss at the NE. Even though the equipment is exempt from compliance in this particular case, the vendor shall still supply a clear specification of the equipment's receive return loss so that it can be properly engineered into the network.

The network engineer may need to add loss at the transponder's coupler in order to achieve a return loss that is sufficient to avoid impacting other services offered in the band.

5.7.22 Transmitter slew rate

The slew rate describes how quickly the transmitter moves from transmitting a logical '0' to a logical '1' and vice versa. For both the forward and return channels, the transmitter's transition time between binary states must be controlled to ensure that the signal frequency is within 13,4 kHz (= $2\Delta f \times 10$ %), for a Δf = 67 kHz, of the initial and final values of $+\Delta f$ or $-\Delta f$, within the specified time.

5.7.23 Transmitter on/off ratio

The transmitter on/off ratio is the ratio between the 'on' transmitted power and the 'off' transmitted power.

5.7.24 Modulation technique

The modulation technique is the method by which digital information is impressed into the analog channel. In this case, the modulation is binary frequency shift keying (FSK) with the two shift tones at $\pm\Delta f$ from the centre frequency. A logical '1' is mapped to the upper of the two shift frequencies and a logical '0' is mapped to the lower of the two shift frequencies. The notation f_c denotes the centre frequency of the channel and Δf denotes the FSK frequency shift. The 'mark' (logical '1') frequency is $f_1 = f_c + \Delta f$ and the 'space' (logical '0') frequency is $f_0 = f_c - \Delta f$.

5.7.25 Bit rate

The bit rate is the nominal transmission rate for the channel.

5.7.26 Bit rate accuracy

The bit rate accuracy is the maximum deviation from the provisioned value of the bit rate. It is valid over the full temperature range specified for the equipment.

5.7.27 Transmitter power delta between 'mark' and 'space'

The transmitter power delta between 'mark' and 'space' is the difference between the peak power of the 'mark' signal and the peak power of the 'space' signal.

5.7.28 Transmission duplexing

This specifies whether a device supports full-duplex or half-duplex operation.

5.7.29 Transmission mode

The transmission mode describes the overall mode in which the physical layer transmits data. Bytes on both the forward and return channels are transmitted asynchronously. Both the forward and return channels are packet-based; however, they differ in how they handle the gaps between packets. On the forward channel, the transmitter is continuously on. It rests on

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‘mark’ between packets. In contrast, the return channel transmitter turns off between packets. It does this to support multiple access on the many-to-one return channel.

5.7.30 RF connector

This specifies the type of RF connector that shall be supported. Support for an RF connector option depends on the transponder type as defined in Table 1.

5.7.31 Operating temperature range

This specifies the minimum set of temperatures over which HMS compliant transponders shall operate and meet this specification.

5.8 Media access control layer interface

The PHY layer delivers bytes to and from the Media Access Control (MAC) Layer based on its detection of the incoming signal. The exact method for delivering these bytes is left to the vendor. The physical layer could also deliver an indication of ‘insufficient power’ to indicate periods during which the quality of the received signal is too low to reliably detect binary 0’s and 1’s. The MAC layer can use this information to help it determine the beginning and end of packets. The exact method for declaring ‘insufficient power’ is left to the vendor.

5.9 RF cut-off

RF cut-off is required on the return channel to shut down transponders that have failed with their transmitter ON. A transponder in this state is often referred to as a ‘babbler’. RF cutoff shall be invoked automatically to ensure a transponder shall never leave its transmitter ON for more than 1 s after it has been enabled or when a message is received from the head-end indicating that the RF output should be cut off. The cut-off time shall be such that, after taking into account timer inaccuracy, the RF transmitter shall be cut off within 1 s after it has been enabled. The cut-off mechanism should protect against all reasonably likely failures including a microprocessor failure. When cut off, the transponder’s RF output power should meet the on/off power specification in 5.7.23. RF cut-off is not required on the forward channel.

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